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Facilitating automated driving

Task 1: Identification of requirements towards network operators

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Preface

The sub-activity 4.2 ‘Facilitating automated driving’ of EU ITS Platform has a scope to prepare road authorities and operators to make decisions on facilitating automated driving and automating their own core business. This is a report of task 1 ‘Identification of requirements’. This task initially focused on the requirements of higher levels of automated driving, and especially the requirements of automated driving towards the road authorities and operators concerning road markings, traffic signs, real-time and predictive traffic information, digital maps, cooperative ITS infrastructure and other aspects. The scope of the deliverable was then extended to encompass requirements of automated driving to ensure the safety and the efficiency of the transportation system.

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1. Introduction

The sub-activity 4.2 ‘Facilitating automated driving’ of EU ITS Platform has a scope to prepare road authorities and operators to make decisions on facilitating automated driving and automating their own core business. It has a task to identify requirements. Specifically, this task first focused on the requirements of higher levels of automated driving, and especially the requirements of automated driving towards the road authorities and operators concerning road markings, traffic signs, real-time and predictive traffic information, digital maps, cooperative ITS infrastructure and other aspects. The scope of the task was then extended to encompass requirements of automated driving to ensure the safety and the efficiency of the transportation system.

The deliverable starts with an overview of the levels of driving automation as well as some basic definitions (chapter 2). The purpose of this deliverable is to describe the state of the art of the automated driving (Chapter 3), and the expectations that general public, commercial vehicles and fleets and road network managements have on automated driving (Chapter 4). A key factor in determining the requirements of automated vehicles is their Operational Design Domain (ODD), which is looked at in Chapter 5. The deliverable describes also the identified requirements toward physical (Chapter 6) and digital (Chapter 7) infrastructure. In addition, it discusses topics related to legal and regulation framework (Chapter 8), and also lists the related national strategies and actions (Chapter 9). In the end, conclusions are made (Chapter 10).

2. Basic definitions and levels of driving automation

2.1. Basic definitions

An **automated vehicle** is a vehicle equipped with an automated driving system. That is a system which is able to at least carry out steering and acceleration/deceleration and the monitoring of the environment.

An **autonomous vehicle (or a system)** is an automated vehicle (or system) that is able to perform its tasks independently and self-sufficiently (SAE 2016), i.e. without actions or supervision of a human driver, and without communication and/or cooperation with other entities.

A **connected vehicle** is a vehicle with communication capabilities able to receive and send data about its environment, the traffic situation or driving conditions to other vehicles (vehicle-to-vehicle communication, V2V), the network operator (vehicle-to-infrastructure communication V2I) or its manufacturer and service providers. A connected vehicle would not necessarily be an automated vehicle.

A **cooperative vehicle** is a connected vehicle with communication capabilities that comply with C-ITS standards (ISO or ETSI).

2.2. Levels of automated driving

Vehicles with automated driving capabilities can be classified in different automation levels with respect to situations and driving modes an automated driving system can cope with. The most used scale is published by SAE international and J3016 (SAE 2016). It contains six levels ranging from no automation (Level 0) to fully automated driving in all modes and situations (Level 5). The following (**Table 1**.) summarizes automated driving levels and corresponding capabilities and limitations. These levels will be used in this report while describing the different levels of vehicle automation.

This report focuses on Level 4 requirements, since this level is the goal for all car manufacturers and it has the strongest and widest requirements towards road operators. Furthermore, several car manufacturers, e.g. Volvo and Ford, have announced their intention to entirely skip the Level 3 in their automated driving system research and already target higher levels, 4 and 5.

Table 1. Summary of Levels of Driving Automation for on-Road Vehicle Copyright © 2016 SAE International.

Abbreviations: ADS = automated driving system, DDT = dynamic driving task, OEDR = object and event detection and response, ODD = operational design domain.

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	OEDR		
Driver* performs part or all of the *DDT						
0	**No Driving Automation**	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	**Driver Assistance**	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	**Partial Driving Automation**	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
***ADS* ("*System*") performs the entire *DDT* (while engaged)**			*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
3	**Conditional Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.				
4	**High Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	**Full Driving Automation**	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

3. State of the art of automated driving systems and automated vehicles

3.1. Automated driving systems

Currently, the progress in development of automated driving systems varies from manufacturer to manufacturer. Most if not all of the major players in the automotive industry have already added basic automation capabilities to their vehicles that are already on the market:

- Cruise control

  Cruise control is a system that automatically controls the speed of a motor vehicle. The system is a servomechanism that takes over the throttle of the car to maintain a steady speed as set by the driver.

  Adaptive cruise control is an optional cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead. It makes no use of satellite or roadside infrastructures nor of any cooperative support from other vehicles. Hence control is imposed based on sensor information from on-board sensors only.

  Cooperative adaptive cruise control is a cruise control system that add communications with nearby vehicles to enhance reactivity and precision.

- Lane departure warning or lane keeping assistance

  Lane departure warning system is a mechanism designed to warn the driver when the vehicle is about to leave its lane unintentionally (the turn signal is an indicator of that intention) on freeways and arterial roads.

  Lane keeping assistance is a further development of the modern lane-departure warning system. The lane-keeping assist system is able to support the driver in staying within a lane. This means it combines the features of a convenience system with those of a warning system. The system usually assists the driver through electronic assistance with the steering force.

- Emergency braking system

  Advanced emergency braking system is an autonomous road vehicle safety system which employs sensors to monitor the proximity of vehicles in front and detects situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent. In such a situation, emergency braking can be automatically applied to avoid the collision or at least to mitigate its effects.

- Parking assistance

  Parking assistance system can steer the car by itself into a parking space with little or no input from the user.

- ADAS (Advance Driver Assistance System)

  Advance Driver Assistance System supports the driver in the driving process. It's the topic of any system which is developed to automate and enhance vehicle systems to improve safety as well as the comfort.

There are numerous systems on the market, at the time of writing this deliverable, for example the Autopilot system from Tesla motor and the Intelligent Drive Driving Assistance package from Mercedes-Benz. Those systems belong to Level 2, partial automation systems since the driver still needs to monitor the driving environment to be able to reclaim control of the vehicle at any time.

Tesla's Standard Autopilot features include: Autosteer to steer within a lane; Traffic-Aware Cruise Control to maintain the car's speed in relation to surrounding traffic; Auto Lane Change to assists in transitioning to an adjacent lane on the right or left side of the car when it is safe to do so when Autosteer is engaged; and Autopark to indicate a parking spot while driving at low speeds on urban streets and to manoeuvre the vehicle into the parking space.

Mercedes-Benz's Intelligent Drive features include: Distance Pilot to automatically maintain the correct distance to vehicles in front and to follow traffic ahead in its lane at speeds of up to 200 km/h; Steering Pilot to keep the vehicle on the lane (not dependent on clearly visible lane markings, up to speed 130 km/h); Speed Limit Pilot with COMAND Online to adjust the vehicle's speed in response to camera-detected speed limits or speed limits logged in the navigation system; Active Brake Assist to warn the driver of imminent crash situations, to optimally assist them during emergency braking and, if necessary, also to initiate automatic autonomous braking; Cross-Traffic Function of Active Brake Assist to detect crossing traffic and pedestrians in the danger area in front of the vehicle; Evasive Steering Assist to help to pass a pedestrian safely by adding precisely calculated steering torque to support the movement of the steering wheel; Active Lane Keeping Assist to help stop the driver from unintentionally changing lane; Active Blind Spot Assist to warn of the risk of a lateral collision and likewise correctively intervene at the last moment to prevent a collision; and PRE-SAFE® PLUS to protect against collisions with traffic following behind.

3.2. Automated vehicles

Experiments on automating vehicles have been made since at least the 1920s. The first self-sufficient and truly autonomous prototype cars appeared in the 1980s, with Carnegie Mellon University's Navlab and ALV projects in 1984 and Mercedes-Benz and Bundeswehr University Munich's Eureka Prometheus Project in 1987 (Wikipedia 2016).

Table 2 summarizes major personal car manufacturers' plans for high level automated vehicle as listed by Chan (2017).

Table 2. Advanced driver assistance systems and higher level automated driving system introduction or expected introduction (Chan 2017).

Organization	Confirmed and predicted product introduction	Predictions of readiness for Level 4 vehicles
Audi/VW	2016 - Piloted Driving	Full AV by 2021
BMW	2014 – traffic jam assist 2014 – automated parking	Available by 2021
Bosch	2017 – Integrated Highway Assist 2020 – Highway Pilot Auto Pilot	by 2025
Continental		Available by 2020
Daimler Benz	2014 – Intelligent Drive	Available by 2020
Ford	2015 – fully assisted parking	To mass produce AV in 2021
GM	2017 – Super cruise	
Google	2015 – Driverless Pod prototype	Available by 2018
Honda		Available by 2020
Hyundai		Available by 2030
Mobile Eye	2016 – technology ready for OEMs	
Nissan	2016 – traffic jam pilot 2018 – multiple lane control	Available by 2020
Tesla	2015 – Lane Assist + ACC	highly autonomous Self-driving 2020–2025
Toyota		Mid 2020s – highly autonomous
Volvo	2015 – traffic jam assist 2017 – Drive Me FOT in Sweden	Zero fatality cars by 2020

Testing of Level 4 and 5 automated vehicles on open roads is in progress in several countries. Because of the small number of vehicles and their prototype nature, these tests or test vehicles are not included in the table above. Nevertheless, as some of these experimentations have started to yield information on requirements towards infrastructures and operators, they have been taken into account in latter chapters of this report.

In 2017, the ERTRAC task force on "Connectivity and Automated Driving" published roadmaps for Level 3 automated driving. The expected time frame for conditional automated driving industrialization was 2020 to 2022, for long distance travel with automated commercial vehicle was 2022 to 2024.

Being driven by marketing imperatives, car manufacturers are more optimistic than the ERTRAC task force but the announced dates for Level 3 automation are reasonably close. On the other hand, most announcements of vehicle manufacturers concerning the roll-out of highly automated vehicles have in 2018 referred to Level 4 vehicles and thereby Level 3 has been evidently skipped by most.

4. Expectations on automated driving

Automated driving systems are developed and regarded as a way to bring improvement to the following issues:

- Road safety: by reducing most crashes which involve human errors
- Efficiency: the transportation system efficiency could be increased by reducing congestion via better utilisation rates or via increase in capacity, and by reducing energy consumption and vehicle emissions
- Comfort: users comfort while travelling could be improved by enabling them to rest or pursue other activities.
- Provide with new freedom and enhanced mobility for disabled individuals.

Other long term expectations where automated vehicles could boost the development include improvement of mobility for everyone by facilitating new mobility as a service concepts and disconnecting the ability to travel from the material possession of a car and city centre accessibility.

Expectations concerning automated vehicles in general can vary widely depending on the actor position in the driving ecosystem. Drivers of personal cars and commercial vehicles have a different set of expectations, as well as fleet managers, transport network managers and operators, and car manufacturers.

4.1. General public

General public's expectations are well known. Several studies and surveys have been carried over the past years by various researchers to better understand drivers and evaluate the market. However, there is a gap between what the general audience expects to be possible in the short term versus what is realistically available. Steven Shladover describes this so-called disconnect in an article in Scientific American (The truth about "Self Driving" cars, June 2016).

A survey about the general public acceptance of automated cars and its readiness to switch to a car equipped with an automated driving system was published in March 2016 (L'observatoire Cetelam 2016) and carried across several countries, of which in Europe: Belgium, France, Germany, Italy, Poland, Portugal, Spain and the United Kingdom. According to this survey, the public's primary expectations toward automated vehicle were improved safety and security, savings of money and savings of time with comfort as fourth priority, almost as important as the first three. The main concerns expressed about automated vehicles were related to relinquishing the full control of their vehicle, the use of collected data, and a general concern about safety.

4.2. Commercial vehicles and fleets

Commercial vehicles and specifically the automated trucks are expected to help the transportation industry to optimize fuel consumption, travel time and cost of transporting goods.

Fuel and driver are two of the most expensive cost items in goods transportation. An automated truck could be set to travel at an optimized speed for fuel consumption, something that is not possible today due to the driver presence and the need to adapt the journey to driving time and rest regulations.

In the absence of drivers, fleet usage optimization could be enhanced a lot for goods transportation vehicles, but also for rental or person transportation service. Such vehicles could be easily moved to meet expected demand and, in the case of taxis, be used for a greater fraction of the day with down time only for cleaning, refuelling and maintenance.

Automated trucks would also ease the platooning of several vehicles. In addition to the other benefits of automated truck driving, the main advantages of automated truck platooning are:

- Improved fuel efficiency and decreased CO_2 emissions
- Improved efficiency for traffic flow (throughput). Since trucks drive more closely to each other, traffic density is increased and tail-back is reduced. There's also increased stability of the traffic flow due to reduced string instability as a result of the communication between the trucks in a platoon

Since the automated driving system take control of trucks in platoons, platoon's vehicle-to-vehicle communication would be possible and very efficient, and given that an automated system has a virtually inexistent reaction time, all platoon trucks would be able to brake at once, thus improving safety.

4.3. Road network operators and managers

Road network operators and traffic managers expect traffic safety to improve with the introduction of automated vehicles e.g. because of their compliance with speed limits and safety gaps and of their quick reaction times. However, since the aim of a traffic management is also to ensure that its network allows the traffic to flow efficiently, the introduction of automated vehicles would be badly received if they cause networks efficiency to decrease due to e.g. inability to interact with other road users.

If manufacturers and network operators work together, automated vehicles could actually be an opportunity for gaining better knowledge on the network state and implementation of more sophisticated network management strategies. It is expected that connected automated vehicles will share a lot more information about their environment than non-connected and non-automated vehicles. Network managers could use more traffic data to

better adjust their network operation strategy and improve their network overall efficiency with an improved situation awareness. Due to the extended knowledge of the road network the road operators can better plan and organize any measures belonging to road maintenance on the network – construction sites, improving road construction and/or surface and even grass mowing.

Eventually, the share of automated vehicles in the general traffic will be high enough and given that an automated vehicle will have higher compliance rate to network management instructions and advices (provided the information is widely broadcasted and reach these vehicles), the network management strategies will have a greater impact and may have to be adapted or made targeted. For example, in order to avoid saturation on urban network in case of an accident on a nearby motorway, a network manager could allocate the vehicles driving on the affected road to several alternative itineraries in order to decrease the congestion on the motorway without creating too much saturation on network used for rerouting traffic. However, to achieve network optimum like this, cooperation between traffic operators and car (or navigator) manufacturers is needed on development of routing strategies.

This higher compliance from automated vehicles could also be an advantage for modelling of the traffic flow. Taking into account the human factor is an important part of current research on traffic models and one of the reasons a traffic model has to be calibrated - a tedious, long and complicated process - before being put into use. Possibly, modelling automated vehicles in traffic could be easier and more reliable due to a deterministic decision process based on programming. However, as there will be variance and timely development also among the automated vehicles due to different makes, models and software versions, also their drive behaviour models need to be calibrated.

The introduction of highly automated vehicles is also blurring the lines when discussing about the role and responsibilities of each stakeholder. One of the main variables remains data property and it can have a significant impact on roles, like traffic manager. Every stakeholder and especially road operator could change roles in certain specific areas.

5. Operational Design Domain

5.1. Relevance of ODD for automation use cases

Operational Design Domain or ODD is a description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/ night time, etc.), prevailing traffic law and regulations, and other domain constraints. An operational design domain can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours. (Waymo 2017)

The ODD is relevant to all levels of automation except for 0 and 5 as shown in Table 3. Any automation use case of level 1-4 is usable only in its specific ODD.

Table 3. ***Relevance of Operational Design Domain ODD for different automation levels (SAE 2016)***

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	*OEDR*		
Driver* performs part or all of the *DDT						
0	**No Driving Automation**	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	**Driver Assistance**	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
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***ADS* ("*System*") performs the entire *DDT* (while engaged)**			*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
3	**Conditional Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.				
4	**High Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	**Full Driving Automation**	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

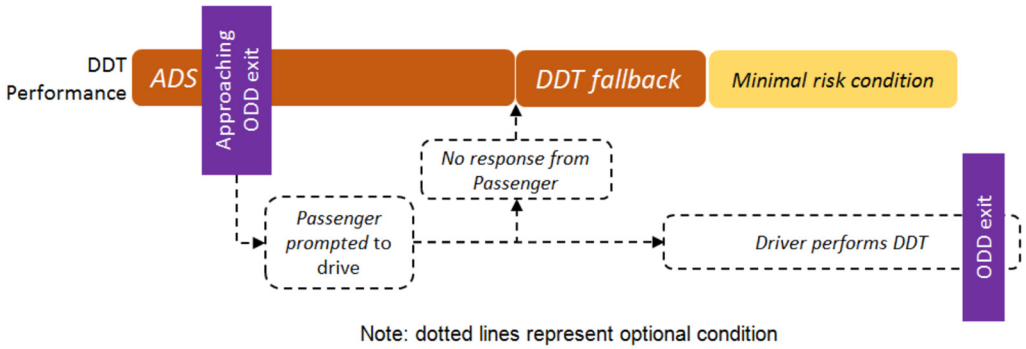

Figure 1. Performance of automated vehicle when approaching ODD exit. ADS = Automated Driving System; DDT = Dynamic Driving Task. (SAE 2016)

The automated vehicles are deployed so that they consider the ODD and especially its ending. This is illustrated in Figure 1.

The Automated Driving System ADS becomes aware of the impending exit from the ODD and prompts the passenger to take over the tasks of the driver. If there is no response from the passenger indicating takeover, the system initiates Dynamic Driving Task (DDT) fallback and moves to a minimal risk condition. The characteristics of automated achievement of a minimal risk condition at level 4 will vary according to the type and extent of the system failure, the ODD for the ADS feature in question, and the particular operating conditions when the ODD exit occurs. It may entail automatically bringing the vehicle to a stop within its current travel path, or it may entail a more extensive maneuver designed to remove the vehicle from an active lane of traffic and/or to automatically return the vehicle to a dispatching facility. (SAE 2016)

For the user, it would likely be more comfortable the less times the control of the vehicle needs to be transferred between ADS and the driver. It is also likely that elimination of the transfer situations requires investments from the stakeholders responsible for the existence of the ODD in the specific situation. Hence, the continuity and length of the ODD play an important role for both the user and those responsible for maintaining the ODD.

The attributes of the ODD are connected to the way the automated driving system works. ***Figure 2*** shows the example from General Motors.

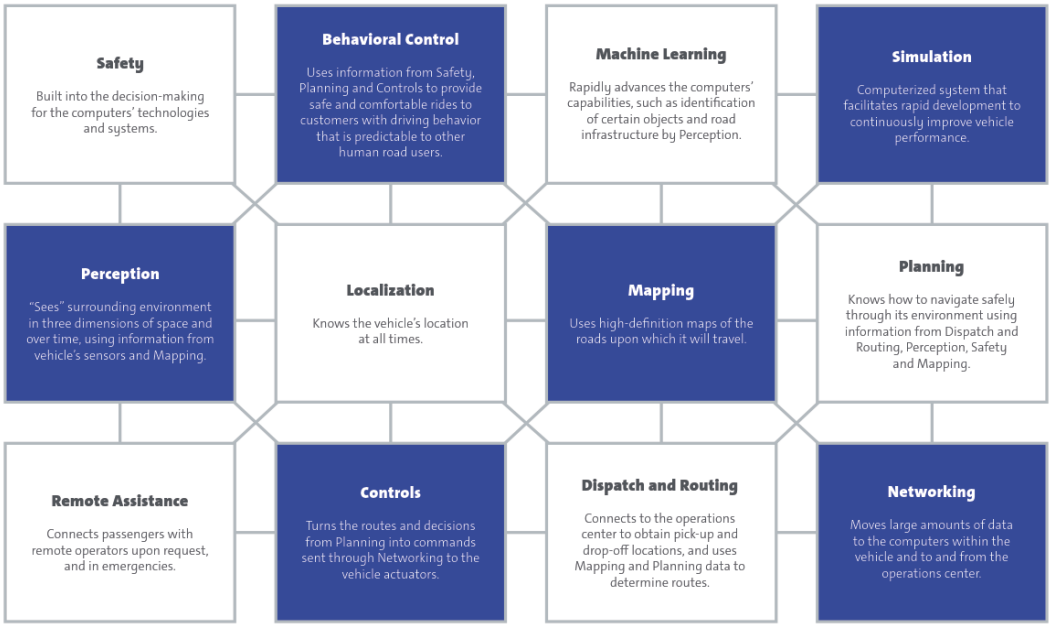

Figure 2. The building blocks of the automated driving system (General Motors 2018)

Perception, accurate positioning and mapping are evidently the key building blocks in the automated driving systems' architecture. The sensors and their range are essential especially with regard to the speed ranges possible (Schoettle 2017). Connectivity/networking to operations centres and real-time information are also important elements. All of these are also related to the vehicle's interaction with its environment, and thereby strongly connected to the ODD.

So far, automated driving use cases have been developed and piloted by various stakeholders without any real coordination. Hence, the stakeholders have made their own decisions concerning the sensor choice, connectivity, positioning options utilised and other factors determining the ODD with only the global, national, and local regulatory frameworks affecting their choices. At the same time, the stakeholders have not published any accurate information about their ODD details as long as the use cases are still not rolled out into the market. There are also proponents calling for more coordinated and interoperable manner to deploy automated driving. Alonso Raponso et al. (2017) recommend Coordinated Automated Road Transport (C-ART). C-ART is meant as an extension of the automated driving concept by adding communication capabilities that connect vehicles in between and with the infrastructure and adding a central coordination player to achieve the full potential of automated driving in terms of social, economic and environmental benefits. Such a coordinated approach would require an additional ODD layer, but on the other hand provide more harmonisation of the ODDs between the stakeholders.

So far, the manufacturers and/or designers of automated driving systems have only published ODDs for urban cars in their voluntary safety reports (Ford 2018, General Motors 2018, Waymo 2017). For other use cases, we are forced to make assumptions on the ODD

features of the five automated driving functionality based on pilots, studies and expert views expressed in various working groups, articles or conferences. The assumed specification for the ODD of each chosen functionality (requirements for physical and digital infrastructure) is presented in the following section.

5.2. Static attributes of ODD

At least the following static ODD attributes may be relevant to an automated road vehicle use case: (Kulmala et al. 2018)

- Road as well as road type
- Speed limit
- (hard) Shoulder
- Road markings
- Traffic signs
- Road furniture
- HD Map
- Satellite positioning
- Communication
- Information system
- Operations centre

These are explained shortly below.

Road

This attribute relates to the type of road itself (motorway, dual-carriageway road, one carriageway road), the number of lanes, road section type (link, grade-separated intersection, level junction, ramp, tunnel, bridge, etc.), and use restrictions (public transport, automated vehicles, trucks, etc.).

Speed limit

Speed limit is important as it relates to the performance needed from the perception sensors of the vehicles. For instance, cameras with the typical operating range of 130 m and LIDARs with 150 m (Schoettle 2017) could be sufficient for a vehicle running at 60 km/h or less but likely not so for one at more than 100 km/h.

Shoulder

The existence and width of a paved shoulder is important in order to enable a safe location for transferring to a minimal risk condition. The other uses of the shoulder area, such as hard shoulder running during rushhours is relevant.

Road markings

The type, existence, condition and visibility of road markings are important to vehicles utilising road markings for positioning or other purposes. Sometimes traffic management information such as speed limits, lane use restrictions, overtaking or lane change

prohibitions are also indicated by road markings. Compliance of markings to national, European or global standards is also important.

Traffic signs

The type, condition and visibility of traffic signs have similar importance as the road markings. Also the compliance of traffic signs to national, European or global standards is important.

Road furniture

The road furniture with regard to ODD contains e.g. landmarks for positioning support, gantries, barriers and gates for restricting access to dedicated lanes or areas, or special furniture for road works. The landmarks could also be equipped with sensor reflectors or communication beacons to make their perception and use easier for the vehicles.

HD Map

The existence, contents and up-to-dateness of HD maps and even the reliability is essential for the accurate positioning of the automated vehicle and planned manoeuvres.

Satellite positioning

Satellite positioning is also essential to the positioning of the vehicles either as the primary or secondary location solution applied by the automated driving use case. The positioning by satellites is made more accurate with the help of fixed land stations (RTK, Real Time Kinetics), which are useful especially in city areas with high buildings, hilly/mountainous areas or northern/southern latitudes.

Communication

Connectivity is essential when an operations centre connection is utilised for the use case e.g. to facilitate remote control for temporary loss of ODD or when real-time event and traffic information is needed to provide the electronic horizon or local dynamic map for the automated vehicle or when the communication is an element of the use case as in platooning. The communication reliability, latency and coverage needs of the use case determine the type of communication media to be used.

Operations centre

An operations centre is already used by developers (e.g. Waymo 2017) of automated driving to supervise the operation of the vehicles. Operations centres are essential for use cases where the passengers of the automated vehicles expect continuous travel to their destination despite occasional temporary lack of ODD. Such use cases are for instance robot taxis or public transport shuttles. The centre is monitoring the operations of the vehicle fleet and may take control of the vehicle when this is needed. For this purpose, the centre needs short-latency communications with the vehicle and its sensors and control devices.

Information system

The information system is part of the back-office systems of the automated vehicle use cases. The traffic rules and regulations in digital form related to the area and even the road section is a necessary part of the information system. The system might contain real-time traffic information on incidents, roadworks, events, congestion and other disturbances on the road ahead needed for tactical decisions on route choice, lane selection and safe speed choice. The system might also contain data from the automated vehicle and its sensors for later analysis and utilisation.

5.3. Dynamic attributes of ODD

The dynamic attributes of ODD include at least: (Kulmala et al. 2018)

- weather and road surface condition
- road condition
- roadworks
- dynamic traffic management

Weather and road surface condition

While the automated vehicle will operate in dry road surfaces on a sunny day, it might not in adverse weather (heavy rain, snow, fog) and road surface conditions (ice, snow, water on road) due to perception and positioning problems. The road operator could ensure that road markings and traffic signs are detectable, visible and in sufficiently good condition also in adverse weather and road surface conditions via asset management and winter maintenance. This means increased costs. For example, in Nordic conditions, this could double the costs of winter maintenance, however (Innamaa, et al. 2015).

Road condition

The road condition, such as bearing capacity, can be temporarily deteriorate due to spring thaw process or preceding heavy vehicles preventing the use of the road section or bridge for 5-20 seconds or for some days or weeks. Such restrictions need to be communicated to the vehicles and their operators via wireless communications or roadside signs.

Roadworks

Roadworks might result in the temporary loss of ODD unless they are marked and equipped in a standard manner comprehensible also to automated vehicles. In any case, the existence, type and exact location of the road works need to be communicated to the automated vehicle via wireless communications or roadside signs.

Dynamic traffic management

The dynamic traffic management contains provision of real-time information of incidents events, end of queues, diversions and routing recommendations as well as dynamic traffic

control in the form of variable speed limits and lane use restrictions. This can also include dynamic access control to specific areas, e.g. ports and logistics centres, residential areas, roads dedicated to automated vehicles during night-time hours, etc.

5.4. Exemples of ODD

Two examples of ODD are presented below – highway autopilot based on C-ITS platform work (Kulmala et al. 2017), and robot taxis based on Waymo's safety report (Waymo 2017)

5.4.1. HIGHWAY AUTOPILOT INCLUDING HIGHWAY CONVOY (L4)

According to ERTRAC (2017), the system provides automated driving up to 130 km/h on motorways or roads similar to motorway from entrance to exit, on all lanes, including overtaking and lane change. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at non-critical times override or switch off the system. There are no requests from the system to the driver to take over when the system is in normal operation area (i.e. on the motorway). Depending on the deployment of cooperative systems, ad-hoc convoys could also be created if V2V communication is available.

The ODD-related requirements were identified for the use case in the C-ITS Platform's Physical and Digital Infrastructure Working Group (Kulmala et al., 2017), and compiled by Kulmala et al. 2018) to Table 4.

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Table 4. ODD related requirements for highway autopilot (L4). (Kulmala et al. 2018)

Highway autopilot incl. highway convoy	
Road	Motorway or similar, only on line sections not including ramps or intersections, but containing straight driving on weaving sections
Speed range	Up to 130 km/h; some systems do not work below 30-40 km/h; no restrictions 2030-
Shoulder or kerb	Safe stopping for a minimal risk condition requires a wide paved shoulder available for this purpose and not used for, e.g. hard-shoulder running. Safe refuges or shoulder areas similar to bus stops could be made available in case of narrow shoulders at intervals of e.g. 500 m on each carriageway
Road markings	Minimum quality of solid or dotted lines painted on the pavement if accurate lateral positioning is based on a camera detecting the location of the lane borders, and if the lines indicate traffic management information (e.g. no overtaking or lane change)
Traffic signs	Needed for vehicle to react to traffic control indicated by traffic signs along its trajectory to select appropriate speed or to take other required action. The sign content can be accessible via cloud, or tags and/or beacons attached to the sign
Road furniture	Wireless radio beacons or physical landmarks possibly with sensor reflectors to support and increase positioning accuracy for AD vehicles. This is most valuable in tunnels and in totally open areas with no fixed objects nearby, or on sections with high likelihood of poor road weather conditions; or when some objects in the environment interfere with the vehicle's sensors.
Traffic	Not in incident situations with people on roadway, or other safety information cases
Time	No specific requirements
Weather conditions	All conditions except for heavy rain or snowing, or road covered with thick layer of snow or water, or in some cases sun glare, heavy fog, or darkness without lighting, 2030- only most severe restrictions apply such as floods, thick snow, etc.
HD map	HD Map of minimum quality needed if the lane identification and accurate lateral lane positioning solution is based on satellite positioning with 3D HD map matching.
Satellite positioning	Needed if the road position, lane identification and accurate lateral lane positioning solution is based on satellite positioning with 3D HD map matching. Satellite positioning accuracy is supported by land stations (e.g. RTK) and possibly also by landmarks on problem sections (tunnels, forests, ...) and conditions (weather).
Communi-cation	Needed for end of queue, lane change, and merge situations for negotiations among vehicles and for maintaining a local dynamic map. Short latency V2V communication is a necessity for highway convoy. V2I communication can be used to receive traffic management information in addition to real-time information.
Information system	Real-time traffic information on incidents, roadworks, events, congestion and other disturbances (SRTI - Safety Related Traffic Information) on the road ahead are needed for tactical decisions on route choice, lane selection and safe speed choice. Digital rules and regulations as well as a geofencing database are also needed.

5.4.2. COMMERCIAL DRIVERLESS VEHICLES (L4) AS TAXI SERVICES

The automated taxi service operates without a human driver transporting passengers from their origin to their destination within the boundaries of a specific geographical area. The ODD specification is based on the Waymo's self-driving car concept (Waymo 2017).

Waymo's system includes three types of LiDAR developed in-house: a short-range LiDAR giving an uninterrupted view directly around it, a high-resolution mid-range LiDAR, and a long-range LiDAR that can see more than 200 m away. Their vision system also includes colour cameras designed to see the world in context, as a human would, but with a simultaneous 360-degree field of view to spot traffic lights, construction zones, school buses, and the flashing lights of emergency vehicles. The high-resolution cameras are designed to work well at long range, in daylight and low-light conditions. Waymo's radar has a continuous 360-degree view to track the speed of road users in front, behind and to both sides of the vehicle. Waymo vehicles also have a number of additional sensors, including an audio detection system to detect police and emergency vehicle sirens, and GPS to support the accurate positioning of the vehicle. (Waymo 2017)

Positioning is based on a 3-D map built during mapping drives with test vehicles equipped with the vision sensors listed above. These maps contain also road types, the distance and dimensions of the road itself, and other topographical features. After that, the map is complemented with salient information that includes traffic control information such as the lengths of crosswalks, the locations of traffic lights, and relevant signage. The automated driving system can detect when a road has changed by cross-referencing the real-time sensor data with the on-board 3D map. If a change in the roadway (e.g., a collision up ahead that closes an intersection) is detected, the vehicle can re-route itself within the system's operational design domain and alert the operations center so that other vehicles in the fleet can avoid the area. In this case, the maps also provide feedback, and the maps can be updated accordingly. (Waymo 2017).

The Waymo ODD covers city streets in good as well as inclement weather, such as light to moderate rain, in both daytime and at night. (Waymo 2017).

The requirements adapted to the common format compiled by Kulmala et al (2018) are shown in Table 5**.**

Table 5. ODD related requirements for commercial driverless vehicles (L4) as taxi services.

Commercial driverless vehicles as taxi services	
Road	Urban road with not too complicated junctions; 2030- all urban roads including ring roads and motorways, rural roads
Speed range	Up to 60 km/h; 2030- up to 80 km/h and then 100 km/h
Shoulder or kerb	Roadside parking space on streets, wide shoulders or refuges on other roads with 500 m intervals; Space needed for passenger hop-ons and -offs, likely clearly marked
Road markings	No specific requirements
Traffic signs	No specific requirements
Road furniture	Possible shelters and seats for waiting passengers
Traffic	Separation of pedestrian/bicycle paths
Time	No specific requirements
Weather conditions	Precipitation <5 mm/h, no ice nor snow on road, no fog/steam/smoke/dust hindering vision; 2030- only most severe restrictions apply such as floods, thick snow, etc.
HD Map	Needed as the lane identification and accurate lateral lane positioning solution is based on vision sensors (especially laser scanners) and satellite positioning with 3D HD map matching.
Satellite positioning	Needed to complement the vision sensor system supported by satellite positioning with 3D HD map matching.
Communication	At least 3G needed for V2I communications with operations centre, 4G or higher for remote control of vehicle.
Information system	Digital traffic rules and regulations, geofenced restrictions

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6. Requirements toward physical infrastructure

6.1. Different road types

According to sensor manufacturers and mapping service providers, each road type brings its own set of problems and performance degradation are not linked to specifically to a given road type. For instance, perception of the road environment will be more critical for urban driving than for rural driving, but on the other hand one can expect digital maps to be better and more up-to-date on urban roads than on rural roads. Since each road type brings its own set of problems, automated driving systems will cope with them differently and with various levels of efficiency and reliability.

Often, challenges for automated vehicles that one may encounter fall in those categories: complexity and velocity. The higher the complexity and/or velocity the more challenging for automated vehicles driving is. One is usually « compensated » by the other: highways have low complexity but high velocities and cities have low velocities but high complexity.

More examples:

- On motorways, the high traffic speeds at which vehicles travel the use of communication between the infrastructure and vehicles is beneficial in increasing their event horizon beyond that of their own current sensors. On the other hand, motorways are usually equipped with the highest sign and marking quality partly due to e.g. the requirements of the EU directive on road infrastructure safety management applying to TEN-T roads (EU 2008), and are also well maintained which give automated driving system a good possibility to position itself on the road.
- Rural roads have less requirements to signs and markings and lower road surface quality but vehicles travel somewhat slower than on motorways. The corresponding environment is usually less cluttered than urban roads which can have parking spots alongside streets, pedestrian crossings, bike lanes, shops and adverts signs, etc. thus making rural roads easier to read and understand for an automated driving system. However, the different road users that can be encountered on urban road can also be encountered on rural roads - sometimes without separation (e.g. in the case of hard shoulder running). In addition, sometimes the speed limits on rural roads are high with respect to the quality of road surface and (lack of) road markings as well as the speed differences of the several road users.
- Urban roads are one of the slowest travelled roads that an automated vehicle can encounter but their environment is highly dynamic with various user categories (pedestrians, bikes, buses, tramways, etc.), traffic lights, parking areas and much higher frequency of conflicting encounters with other vehicles.

Each road type can be managed by a different operator and continuity of automated operation from one network to another will require operators to share procedures, maintenance practices and control standards for example. Given that road networks are usually managed under strong economic constraints, it is possible that the automotive industry will have to carry out most of the work on vehicle side to enable safe and reliable automated driving on all type of roads.

Car manufacturers can address most issues related to the physical road infrastructure as long as those issues are generic enough and are not created by peculiar road network points. For example, such peculiar points can be a very complicated intersection or a one of a kind road development (an example given in *Figure **3***). Addressing those issues would require the automated driving industry to make a comprehensive inventory of entire networks across several countries to identify them. More often than not, road network operators know the peculiarities of their network. Their action on those points would be more impactful than, for instance, renewing road markings on all the rural roads in a given area and upgrading their signs.

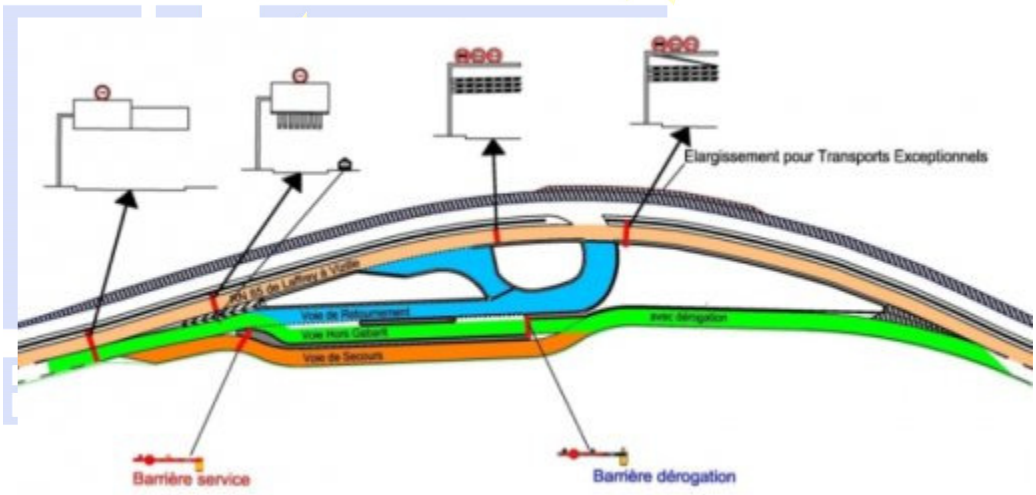

Figure 3: A road section reconstruction on the French national road network. This section was reconstructed after a coach lost braking capability in the Laffrey 12% ramp, killing 27 persons. With two barriers and four gantries, this is a complex implementation on the French road network.

Requirements towards network operators:

- Car manufacturers need consistency within networks and between networks,
- Automated driving system would be easier to develop if there were as few as possible local or national peculiarities to deal with. Operators and manufacturer will need to discuss to find an optimal strategy.

6.2. Quality of existing infrastructure

On one hand, car manufacturers, parts manufacturers, suppliers and related service providers have not expressed specific needs toward the physical infrastructure. The current working hypothesis for the development of automated vehicles is that a quality of infrastructure enough for human drivers should be enough for automated driving systems (EU EIP 2016).

With regard to markings and signs, the automotive industry is satisfied by their state and quality in most, if not all, European countries (EU EIP 2016). With regard to road state, given that an automated driving system could exert a finer and swifter control of a vehicle, the surface state sufficient to guarantee safety to a human driver would be enough for its automated counter-part. Automatic systems like ESC and ABS are already well mastered by the automotive industry and adding an automated driving system to a vehicle would only add more information to ensure vehicle handling. Thus, automated driving should not cause extra requirements on road surface conditions except that the road surface should be kept clean of dirt, snow, ice or other substances covering road markings.

On the other hand, the automotive industry values consistency when it comes to physical infrastructure. The more road configurations, signs and markings are consistent across the network (cross-borders), the less situational diversity an automated system has to cope with. Indeed, a human driver is capable of interpretation and leaves lot of room for potential deviations to expectation whereas an automated system is less flexible. A consistent infrastructure also helps the automated driving system to be more resilient towards degraded conditions like heavy rain or snow. A more resilient automated driving system would be able to function, without having to give back the vehicle control to the human driver, in more driving situations.

Even without manufacturers expecting more from the physical infrastructure, ensuring the consistency of a network may force operators to upgrade their procedures. Control and maintenance are currently mainly determined by a cost/advantage strategy and differs in different parts of the road network (depending on road class, traffic volumes, etc.). This approach can lead to different driving conditions on the same network with sections just good enough for driving and brand new sections with perfect conditions. There are also situations causing problems for automated driving such as detection of an obstacle in the lane, error in digital map, existence or the absence of a hard shoulder, temporary opening of the hard shoulder to traffic, etc. In such situations, automated vehicles could need further information to operate, due to the limited range of their sensors.

Requirements towards network operators:

- Consistency of the quality of road infrastructure on the various road types for continuity of automated driving,

- Possible upgrade on network operators' procedures and quality control to be able to open their network to automated driving systems. Even if the current guidelines for marking, maintenance or signage may mostly be suitable for automated driving, ensuring that level of service continuously could become tricky and costly.

6.3. New or upgraded infrastructures

Automated vehicles may perform better with certain types of intersections than with other. Modelling studies indicate that particularly at high traffic volumes, roundabouts are more efficient for automated vehicles with V2V communications than intersections with traffic signals (Azimi et al., 2013).

Stricter lane keeping of automated vehicles allows narrower lane width and thereby fitting more lanes on the same carriageway improving road capacity. This will also mean that vehicles' wheels run over the same parts of the road cross-section focussing pavement wear on narrow strips along the road, resulting in the formation of wear and deformation ruts on the road. Depending on the percentage of trucks with wider axle width than for cars, the ruts may also be wider. These ruts necessitate shortening of the repaving cycle by perhaps 20%. Otherwise or in addition, changes are needed in road paving so that the narrow strips, where the vehicle wheels run, will be equipped with material tolerating wear better. This material with higher quality aggregate for better wear resistance could be 10-15% more expensive to use. Furthermore, paving equipment could face major changes to facilitate paving of "virtual rails" on the road. In any case, the costs for paving and re-paving will be affected (Törnqvist & Kulmala 2015). Due to safety risks of having humanly operated vehicles using the same roadway than highly automated vehicles, it may be necessary to allocate dedicated lanes or areas for highly automated vehicles during the transitory phase when moving towards road automation. This will likely reduce road capacity.

There is also a need for emergency harbours for malfunctioning automated vehicles or human drivers being unable to regain control in time. In practice, this can be accomplished by using the paved shoulders for this purpose. On the other hand, hard shoulder running has become a popular measure to increase traffic efficiency and use of paved shoulder to accommodate use by stopped automated vehicles can be problematic in such cases.

From several expert's point of view and experience, some example of driving situation causing issues for automated driving system are:

- Roundabout,
- Dynamic lane assignment, and hard shoulder opening for traffic,
- Tolls.

6.4. Classification of infrastructure capabilities

If all roads cannot be built and maintained in the quality required by the automated vehicles, a classification is required on infrastructure capabilities. A regulatory body could first open certain roads to automated driving. Such roads would have the necessary physical and digital infrastructure, suitable maintenance processes and the network operator would have included the presence of automated vehicles in its management strategies. The presence of minimum quality infrastructure capabilities should be provided together with other road attributes.

This supposes that network operators will have to carry an extensive inventory of their network, and set up a system to broadcast the roads classification and updates. Given that digital maps are a crucial component of automated driving systems. This would not be a too high requirement on network operator, except for the inventory and classification work. Since this work would be a one-time task with subsequent upgrades, this should be doable by most network operators.

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7. Requirements towards digital infrastructure

In the context of automated driving and by analogy with the physical infrastructure, the digital infrastructure mainly consists of the information and systems that enable sharing, updating and broadcasting it at the scale of a country, region or road section.

The digital infrastructure is the support for automated driving system's connectivity capabilities. V2I communication does not necessary suppose the existence of a nation-wide digital infrastructure as they can be confined to equipped corridors.

The digital infrastructure encompasses:

- Communication networks: WLAN, ITS-G5, 3G/4G and later 5G, internet of things networks (e.g. Sigfox, LoRaWAN), ITS-G5 Road side units, Mobile edge computing, etc.
- Digital maps and systems to be updated according to the data gathered by automated vehicles
- National single point of access and systems to share, for examples, traffic prevision, road network modifications or road works
- Clouds and back office operations of vehicle manufacturers, service providers, and road operators
- Positioning capability will be provided by satellite system but fixed land stations emitting position signals would make it available in shadow areas or tunnels.

Stakeholders of the digital infrastructure to support automated driving are both private and public. Interoperability, at least on the cloud level, is essential to efficiently enable information to circulate.

A high-quality digital infrastructure is an essential part for the development and reliability of automated driving systems. The amount of data that the automated driving systems are expected to share is staggering. Automated driving systems and connected vehicles send data back to the manufacturer so they can monitor and improve their software[1] which then gets updated over the wireless connection. The same mechanism will be implemented for digital maps and driving condition use cases.

Requirements towards road operators:

- Invest in the parts of the digital. This means at least to build the back-office infrastructure needed to share information and updates, but also to take a leading role to drive third party investments in order to build the digital infrastructure under the responsibility of the network operators. It also means

[1] As of march 2016, Tesla motor was receiving one million miles worth of data from its car (sensors and software debugging information) every 10 hours. https://www.technologyreview.com/s/601567/tesla-tests-self-driving-functions-with-secret-updates-to-its-customers-cars/

having staff aware of the state of the art. Since most stakeholders are from the private sector, agreements and even contracts with the different digital infrastructure stakeholders would be particularly useful.

7.1. Supervision

With the emergence of automated vehicle on the road, the issue of supervision cannot be passed over. Some supervision systems have already been developed and are currently in use in several type of vehicles, such as public transportation shuttles and bus but also in private cars with eCall service for example.

Supervision systems can provide multiple benefits such as safety improvement or fleet management. These systems will have different aims and functionalities based on the type of vehicle it operates. For instance, public transportation, autonomous cab and privates cars represents three different categories in view of supervision requirements.

These requirements may concern:

- Vehicle information's: status (position, speed …), vehicle of user identification, direct environs;
- Permitted actions: rerouting, takeover, emergency stop;
- Driving phases: automation enabled/disabled when the above information/actions are permitted.

Many of the previously stated functionalities will require a specific infrastructure to perform optimally. Most of all criteria there is two that will significantly affect supervision: network coverage, as the ability to the system to read information or take action will be restricted to certain areas, and network latency, as some of those functionalities cannot be implemented out of a specific latency range.

In view of the above it is noticeable that supervision cannot be dissociated from some topics and mainly: cybersecurity, because if supervision tend to improve safety it also create more risk that need to be controlled, and data privacy, especially but not restricted to private cars.

7.2. Digital mapping

Most automated driving systems currently under development heavily rely on digital maps for network navigation and vehicle positioning on roads.

7.2.1. NETWORK NAVIGATION

As for current navigation systems, digital maps are used to compute optimized routes. It can take into account circulation restrictions, for trucks traffic for example, and traffic

information. This use case implies up-to-date network maps, regulation database, real time traffic information and historic traffic data. Though not specific to automated driving systems, those requirements are especially important in this context since automated driving systems may have to take action without human input from the available information. These data and information have to fulfil the same criteria according reliability as the several systems of cars/trucks have to (according to ISO 26262) if the vehicles depend on these data/information. The same requirements also arise for the physical infrastructure, and its quality and appearance.

The road hierarchy and classification is a common issue network operators have with third party navigation systems which remains unsolved today. Depending on the routing algorithm priorities, transit traffic can be navigated via feeder roads through a residential area, for example if such an itinerary is shorter or less congested. This may be a minor problem right now but as automated driving systems become more and more common, more transit traffic could be sent on roads designed to serve housing allotments. For network operator, this would generate safety and maintenance issues. Given the increased criticality of those information, streamlining the sharing and propagation of network modification, traffic restrictions and information will be essential to ensure efficiency at network operator and user levels.

The usability of specific roads and road sections also depend on the occurrence of events and incidents in the neighbouring road networks. The road operators usually deal with such events and incidents with specific traffic management plans, often diverting traffic to specific roads and road sections by specific circulation plans. The traffic management and circulation plans should be also communicated to the navigation service providers.

Requirements towards network operators:

- Share road hierarchy and broadcast networks updates to other stakeholders.
- Share in advance or in real time the traffic management and circulation plans, and the ones to be used in the current situation.

7.2.2. VEHICLE POSITIONING

Once an automated driving system knows what route it should follow, it has to be able to locate itself on the road: where it is on the route, on which lane it is, and where it is in relation to the middle of the lane. It also has to know what to expect from the infrastructure and its environment: the number of lanes, which lane is allocated to a turning manoeuver, and so on.

Knowing what to expect from the infrastructure ahead allows the automated driving systems to make better decisions by comparing what it knows with its sensors' observations. This process is enabled by high definition digital maps. The two main actors of the digital map field, TomTom and Here, are working on solutions to bring detailed knowledge of the network to automated vehicles. Not only the road geometry and markings

are mapped, but any detectable features from the environment, also called landmarks (safety and sound barrier, police and directional sign, street lights, billboards, bridges, etc.).

By looking for the landmarks listed above, an automated driving system will be able to position itself on the road within tens of centimetres. This precision would allow automated driving systems to drive safely on roads even with poor markings and in degraded weather conditions. Indeed, the greater the number of reference points, the lower the chance that all of them are undetectable under heavy rain, snow or fog.

Despite the service providers' ability to update such digital maps according to the data gathered by their mapping vehicles or by any equipped vehicles, in a crowdsourcing spirit, infrastructure maintenance will still be useful for automated driving system. Indeed, well maintained roads and well mowed environment, for example, will allow the points of reference to stay in good condition and well visible over time.

On the other hand, the road network operator could benefit from the wealth of data gathered, processed and ordered by high definition map providers to have a more up-to-date and complete vision of their network state. Answering questions like "Are markings worn out on this section?" would be possible without having to send extensive control patrols on the whole network.

Requirements towards network operators:

- Ensure that the road environment is reasonably free of obstacles that could prevent vehicles accurately positioning themselves (for instance, by mowing or ploughing),
- Setup maintenance policies that contribute to the continuity and consistency of reference points.
- Establish processes to share information on both directions about the road, its environment and any installation and take care that the information will be considered.

7.3. Connectivity

Requirements on cooperative ITS are not specific to automated driving system. As for any other source of information, a human driver is capable to interpret and handle with great flexibility incoming information but an automated system can only act according to its programming, rules and models. Thus, the importance of information integrity, correctness and consistency is more important for automated systems than it is for human drivers. In some specific situations (obstacle on the road, closed road or tunnel), cooperative ITS appears to be useful if not required for an autonomous vehicle.

The cooperative ITS connectivity for vehicles with human drivers will likely be sufficient for automated vehicles as such in most cases.

Nonetheless, incoming data from cooperative ITS channels are important for automated driving systems. Getting information on accidents ahead from several sources: the sensors detecting and other vehicles sending information (V2V) on slow moving vehicles ahead or the traffic information provider and the network manager information on accident and its location through road side beacons or by other means, would strengthen the systems' confidence in the information and improve the overall system safety.

In order for the automated vehicles to drive safely and efficiently, they need a good world image which they can construct from several sources: their own sensors, digital maps and communication with other vehicles and the roadside. The added benefit of communication is that the so-called e-horizon can be extended (both in terms of direction and length) and allows for a more proactive behaviour. This can be demonstrated by comparing Adaptive Cruise Control (ACC) with Cooperative Adaptive Cruise Control (CACC). When several vehicles with ACC drive behind each other they will all react to each other with some system originated delay, resulting in string instability (or a "harmonica" effect). But when connectivity is added, those CACC vehicles can drive in a synchronised manner (because their intent is shared) without string instability, having also a positive effect on throughput. For a safe and efficient traffic flow it is better to have connected and automated vehicles.

7.3.1. SHORT-RANGE CONNECTIVITY

To ensure that vehicles can exchange information on the road and thus fully benefit of a cooperative network the infrastructure have to be sufficiently equipped. V2V communications are one part of cooperative ITS and allow vehicles to communicate with each other on a microscopic level, but there are situations where this type of connectivity will not be enough to ensure reliable information. In some use cases, like where the distance between consecutive cars is longer than V2V capabilities, the infrastructure must act as a relay to convey relevant information.

On the other hand, there are many information items that are relevant on a macroscopic level and which can only be gathered by the infrastructure, all kind of traffic data that can be used on a higher level.

To enable these functionalities it is mandatory that roads are equipped with Road Side Units that are capable of V2I communications. While a pure technical approach would be to equip the infrastructure with RSUs in a way that a 100% of roads are covered there are several factors that can reduce the number of units to consider. First, this cannot be economically viable because current RSUs have a fairly low range (300-800 m) and the price of such units is substantial. Second, a fully coverage of RSU might be pointless in specific sections, mostly when there are no intersections nor other changes in the road configuration. However, the environment parameter should also be integrated in the reflection as the range and effectiveness of RSU can be greatly affected by signal interference such as landforms or dense urban areas.

In addition for some use cases, ad hoc connectivity can be applied, alone or in addition with cooperative one, for instance LIFI[2] (light fidelity) connection during platooning.

There is a substantial work of diagnosis to implement C-ITS on specific road section efficiently while keeping reliable communications.

7.3.2. SINGLE ACCESS POINT AND CLOUD

The extension of the electronic horizon of the vehicle requires high quality data of the conditions and situation on the road sections ahead along the route. This likely requires much higher quality than what is today provided by real-time traffic information services.

The data will be managed and provided via clouds. The model that seems to emerge is that a single access point / national cloud will offer an interface with the service providers' and manufacturers' cloud and not directly with the users. According to the results of NordicWay, the timeliness of information will not suffer too much from the additional data transfer nodes in the chain (Lindqvist & Skjetne 2016).

From a public operator standpoint, safety and security information have to be distributed as widely as possible; either using broadcasting channels or through push services with relevant service provider clouds. User access to the publicly broadcasted safety relevant information should not depend on which cloud drivers are connected to.

Single access point is generally viewed as being a state responsibility.

Requirements towards network operators:

- Ensure, together with relevant service providers, the availability of good quality real-time road, traffic, weather, incident and event status data covering the relevant road network
- Contributing to the single access point and share data through it in appropriate intervals or as a push service.

[2] LiFi (light fidelity) is a technology for wireless communication, similar to WI-FI, by using light to transmit data and position between devices.

7.3.3. INTEROPERABILITY

To avoid replicating work on communications and information exchange, already existing standards should be employed when possible. If needs were to arise, they should probably be extended as a public standard before setting up a proprietary approach.

The European TN-ITS action (TN-ITS 2016) has published guidelines, tools and maintains a standard that support this objective for digital maps.

Concerning communications, several standards exist for V2X communications via ETSI ITS-G5. Standards for LTE-V2X are currently being developed. For 5G, the standards are still unclear.

As for navigation system and digital maps, cross-border interoperability is also a must-have feature since it would allow service providers to develop once and deploy in all countries and facilitate cross-border travel while preserving the same level of service.

The network operators should adhere to European or international standards or guidelines to ensure cross-border interoperability and avoid replicating work done elsewhere.

7.4. User aspect

7.4.1. SERVICE SUSTAINABILITY

A risk of the private cloud intermediary between public cloud and users approach would be that users are dependent on the willingness of the cloud owner to maintain its cloud so long as there are users connecting to it.

In case of a one-time cost business model, as soon as the provider migrates away from the current offering, for instance by marketing a new version of its service, he has no incentive to maintain the previous one. In case of a subscription based business model, as soon as the user payments no longer cover the service maintenance costs, the provider may want to cease the service maintenance.

Legislations tackling this possible issue could mandate the obligation for service provider to provide continuity of service solution, in the previous example it could under the form of a supported upgrade path. This would allow providers the opportunity to innovate without having to comply with legislation and rules on service specification.

If the service was providing security and safety information, it is not in the interest of public authorities to allow the breach of the information chain. Interoperability between automated driving system and cloud could give users the possibility to switch to a different provider (i.e. freedom of choice of service) and allow service continuity despite the original provider offering change.

The European Commission could consider mandating the provision of safety related information more clearly (i.e. use of certain standard like DATEX II) than what is currently

done in the delegated act for safety-related traffic information given within the scope of the ITS directive (CEC 2013).

Those requirements are at state and European level. Network operators do not generally have the regulation power to ensure service continuity in time i.e. sustainability but what is mandated for private stakeholders should also be mandated for public stakeholders and among them for network operators. Continuity of service requirement for network operators is also a must-have for other stakeholders, and would allow them to build their digital infrastructure knowing the network operators would not move away from the current solution without providing a replacement.

The network operators should ensure sustainable service provision with long-lasting agreements and contracts with the relevant stakeholders.

7.4.2. CYBERSECURITY

As stated earlier in this report the protection of the computer part of the system must be a top priority from the first experimentations. The fact that it can endanger the safety of, in or around the vehicle is enough to look closely on that part. The risks cover a wide range for both the vehicle and the supervision centre:

- Data interception of V2X or V2I communication;
- Direct attacks on the supervision centre which can paralyse communication or feed fake information;
- Misdirection of a specific vehicle by luring it with fake GPS positions or V2X communication;

Vehicle systems, as well as infrastructures one's, can be accessed either by a remote connection (e.g. intercepting the WiFi signal) or by a physical connection. While it may be difficult to access on-board units on the vehicle, it may be easy to plug in an RSU if no security measures have been taken. The integrity of such a supervision system is the key to maintain a reliable service for connected vehicles and all the more for autonomous vehicles.

Many organizations and companies in the field of computer security have developed specific expertise domains related to automated vehicles and can be of great help in order to diagnose and propose services for both car manufacturers and road operators.

7.4.3. DATA PRIVACY

Today, car manufacturers and service providers exploit data collected from partially automated vehicles operating on the public roads. The more the vehicles will be automated, the more the data will be valuable for manufacturers to evaluate and improve their systems. Should user be allowed to refuse the data sharing? At what cost? Currently, the car owner does not have an option but to accept data sharing if they want the service.

It is challenging to find a balance between level and effort to put into anonymization and the re-usability of data if individual vehicle data is needed. However, as network operators only need anonymized data which is aggregated by road sections anonymization typically should not be too problematic. But since the road operators are not directly connected to the vehicles, the intermediary will have individual data anyway.

Data privacy agencies (ombudsmen) already exist in European countries. Specific regulation on the European level may be necessary for automated driving systems and also for any kind of connection.

8. Requirements towards legal and regulation framework

8.1. Testing and homologation

Manufacturers have no incentives to put “good” (in the sense that such a vehicle considers all the aforementioned societal and technical aspects) automated vehicle on road, unless their responsibilities are engaged in case of accident. This repartition of responsibilities should be clarified by law if necessary, to ensure manufacturers have enough incentive to produce safe vehicles. On the other hand, they will have to create a safe and reliable automated driving system otherwise they risk facing strong public safety reactions.

On Level 4 and 5, since vehicle type approval is currently only physical, something additional has to be devised to cover also the software included. Since it seems hard to test an automated vehicle in enough driving condition to ensure it will answer suitably to real world situations, processes set up in the aeronautic world could provide the basis for highly automated driving systems certification and homologation. For example, the quality control and development process for flight critical software are very strict and well documented and compliance by industry stakeholders is mandatory.

Currently, type homologation can be done once in a European country and still be valid in other countries. A similar way of doing type homologation and development processes certification at European level would avoid putting too much strain on car manufacturers.

It may happen that automated vehicles will be allowed to operate only on specific types of roads and for certain weather conditions. In addition to road operators, it may also be the car manufacturers who define these safe operating conditions for their systems.

However, it is not possible to test all possible real world scenarios before allowing vehicles on the market. And even if testing can be done once with a mutual recognition for all other European countries (as is it now for manual vehicles), a testing framework would cost a lot to elaborate and maintain.

Requirements towards states or at European level:

- Clarify the repartition between stakeholders to ensure they have incentives to design automated driving system with road safety as a key requirement.
- Set-up European-wide type homologation and standards for automated vehicles.

8.2. Type Approval and UNECE WP1 and WP29

The National Regulatory Frameworks have evolved during the time when automation was only a remote possibility. A large number of Member States have either started or a planning to start regulatory process which will introduce the necessary modifications to the existing regulations, or even introducing new elements. The National Regulations cover typically driver behaviour and driving licence (National traffic rules, civil and criminal law,

in particular for ensuring road-safety), and the permissions for testing automated vehicles on open roads including possible derogations to the normal traffic rules. Furthermore, a large number of other areas are impacted through EU and UNECE regulations.

Furthermore, UNECE's Global Forum on Road Traffic Safety (WP.1), has adopted in October 2018 a non-binding legal resolution serving as a guide for the countries which are Contracting Parties to the 1949 and 1968 Conventions on Road Traffic in relation to the safe deployment of highly and fully automated vehicles in road traffic.

The resolution offers recommendations to ensure the safe interaction between automated vehicles, other vehicles and more generally all road users, and stresses the key role of human beings, be they drivers, occupants or other road users.

UNECE's World Forum for the Harmonization of Vehicle Regulations also established a new Working Party on Automated/Autonomous and Connected Vehicles which had its first meeting on 25-28 September 2018), in which it started to address a variety of technical issues, such as technical requirements; cyber security and software updates; and innovative testing methods, in particular the use of simulations.

Therefore, it is imperative for the regulatory authorities of the Member States to participate in the work of UNECE and other EU and international bodies on the work for the renewal of the UNECE type approval system, in particular the work of the new Working Party on Automated/Autonomous and Connected Vehicles. When there will be, based on this work, updates to the EU Type Approval System, they have to be introduced to the national legislation in order to allow sales and operations of commercial automated vehicles (interoperable within Europe, type approved in any EU country)

8.3. Vehicle and systems propriety

More and more manufacturers wish to keep control of the sold vehicles and embedded systems. Nowadays when someone buys an advanced vehicle they have to agree to a contract with the manufacturers by which they allow the manufacturers to retain certain rights on the vehicle. E.g. Tesla is using these rights through their dash board and cellular connection to retrieve data on driving condition, system performance and environment monitoring for them to use in their developments.

Such dispositions may also be used to prevent security researchers, being from publicly funded organisations or not being irrelevant, to perform security analysis of vehicles. In a previous case, a European group of researchers were prevented to publish their work after a car manufacturer took the matter in front of a judge. It took several years of negotiation before publication was agreed upon by the manufacturer.

From a network operator stand point, automated driving system safety and security can undoubtedly gain from being audited and analysed by more experts than just the manufacturers' teams. In the long run, a legal framework to allow such analysis while

preserving the commercials interests of automated driving stakeholder would certainly help to build a safer automated transportation system.

Requirements towards states or at European level:

- Set up a legal framework to proactively protect consumers and network operator rights and interest before overreaching “end user agreement”.
- Set up a legal framework to allow independent researchers to analyse and audit automated driving systems without have to risk facing legal action while allowing industry stakeholders to reasonably preserve their commercial interests.

8.4. Experimentation and innovation

8.4.1. Testing on Open Roads

The applicable legislation for testing of highly automated vehicles on open roads is mainly the national traffic law (traffic rules). Derogations to the normal traffic rules are generally possible and issued by the Member State authorities as allowed by the amended 1968 Vienna Convention, as discussed above.

However, it is not possible to test all possible real world scenarios before allowing vehicles on the market. Therefore, more cooperation including sharing of results is needed. The best what can be obtained at this stage would be to establishing an EU-level mechanism to better coordinate open road testing and exchange on lessons learnt and sharing of results.

The 2018 EC Communication on Automated Mobility (EC 2018a) includes an Action to set up such a European Platform, grouping all relevant public and private stakeholders to coordinate open road testing making the link with pre-deployment activities. The ToR has been published in 2019. The format could be similar to the C-ITS platform with different Working Groups, and the focus of the platform could be on defining a European testing agenda (priority use cases, corridors for testing) including:

- Definition of common KPIs and methodology for Impact Assessment
- Common strategy and guidelines for sharing data of large-scale testing
- Access and exchange of data (public/private, vehicle/infrastructure)

The Regulatory Authorities of all interested Member States should participate in the work of the European Platform being set up by the EC to coordinate open road testing as an action of the Communication on Automated Mobility.

Some examples of specific legislation are shown below for a few countries of the task members and this list is not comprehensive.

8.4.2. FRANCE

In France, an authorization is needed in order to test and experiment an automated vehicle on public roads. It contains specific restrictions in which conditions the vehicle is allowed to engage its automated system, vehicle identification, nominated road sections and duration of the experimentation. Several public institutions examine the case on the following domains: road safety, cybersecurity, route compatibility and public transportation.

During the inspection process, the local road operator and public transportation authority are requested to express an opinion regarding the experimentation. They also work closely with the applicant in case the infrastructure needs upgrades at some point.

This authorization process have seen some evolutions in the last couple of years, among these the possibility to implement autonomous transport service (with access to public) as experimental or experimentation with deported supervision. Some working groups currently aim to elaborate a list of minimum specifications at which any vehicle must comply for a new experimentation. The aim is to speed-up the process of file examination, as for now each application is looked-up closely and independently.

8.4.3. UNITED KINGDOM

Several reviews and consultations examining the existing legal and regulatory framework, and recommending changes have been undertaken in the UK in recent years.

In 2015 the UK Department for Transport (DfT) undertook a detailed review of regulations for automated vehicles. The central finding was that the existing legal and regulatory framework was not a barrier to testing on public roads, providing that a human test driver was responsible for the safe use of the vehicle is present and “alert and ready to resume control” of the vehicle if necessary.

This review also identified a number of actions that the UK government would take including the publication of a Code of Practice to promote safety during the testing phase. It also included a timetable for clarification and necessary changes to legislation to allow these technologies to come to market.

The Code of Practice for testing autonomous vehicles was published in July 2015. It sets out the safety and general requirements and responsibilities of testing organisations, including that:

- Responsibility rests with the testing organisation;
- Vehicles under testing must comply with all relevant road traffic law;
- Test drivers must hold the appropriate driving licence and receive training appropriate to the vehicle;
- Testing organisations should conduct risk analyses of any proposed tests and have appropriate risk management strategies; and
- The statutory requirements on the holding of insurance apply.

In July 2016, the DfT consulted on its broader regulatory approach to Advanced Driver Assistance Systems (ADAS) and Automated Vehicle Technology (AVT). This consultation proposed some changes to the approach to UK motor vehicle insurance (in the UK unlike in some other countries, the driver, rather than the vehicle, must be insured against liabilities). This led to the Government amending its insurance proposal following concerns about the co-existence of product liability insurance law with the current compulsory motor insurance framework.

In November 2018, a review of the UK's regulatory framework to enable safe and effective deployment of automated vehicles on Britain's roads was launched. An initial consultation paper focuses on reforms that will allow automated vehicles to be used:

- Lawfully, without conflict - examining the difficulties of translating the analogue legal rules and developing them into a much more precise "digital highway code" to govern the actions of highly automated vehicles. Three practical examples are included to provide situations when automated vehicles should be required (or allowed) to deviate from road rules: (1) to mount the pavement; (2) exceed the speed limit; and (3) edge through pedestrians.
- Safely – in pre-placement: how the type approval process may work, new national safety assurance schemes that may be required. And then when vehicles are on the road: regulating consumer information and marketing, market surveillance and recalls, roadworthiness tests, driver training, accident investigation; and setting and monitoring safety standards.
- With appropriate legal mechanisms for attributing criminal and civil liability - the regulation of road traffic relies greatly on criminal offences. A background paper to this project has analysed 71 offences which may be committed by a driver, and examines if these would still be applicable and where driver responsibilities may need to be reallocated. Progress has been made in the UK on civil liability with the Automated and Electric Vehicles (AEV) Act 2018. Under this legislation where an accident is caused by a vehicle which is driving itself under the terms of the Act, the insurer is directly liable for

the damage. Once the insurer has settled a claim with the injured party it may then reclaim damages from other parties liable for the accident, such as the vehicle manufacturer.

This review and consultation is part of a three-year project, running from March 2018 to March 2021.

8.4.4. FINLAND

An enterprise, agency or other organisation engaged in research and development of automated vehicles may apply to Trafi for a test plate certificate. The certificate entitles the bearer to drive test vehicles, to a limited extent and on a temporary basis, both in road traffic and off-road. For testing in road traffic, Trafi will issue test plates.

The holder of a test plate certificate for automated vehicle trials may operate a vehicle with test plates in road traffic on a temporary basis without being liable for car and vehicle tax on that vehicle.

The test plate certificate is valid for one year from the date of issue, and it is automatically renewed annually.

8.4.5. GERMANY

The Act amending the Road Traffic Act entered into force on 21 June 2017. This Act contains fundamental rules governing the interaction between drivers and motor vehicles with conditional (level 3) or highly (level 4) automated driving functions. It is an essential basis for acceptance and the safe introduction of automated driving functions in road traffic.

The key element of this Act is the changed rights and duties of drivers during an automated driving phase. Under certain conditions, the driver may divert their attention from traffic and from controlling the vehicle while using conditional (level 3) or highly (level 4) automated driving functions. It is clear that the driver is still on board. However, they may rely on the functioning of the system if they abide by the new rules and, in the event of a system failure, they will not be held liable.

8.4.6. SPAIN

In Spain, Authorization to conduct tests or research trials of automated vehicles on roads open to general traffic is regulated through the INSTRUCTION 15/V-113 of the Directorate-General for Traffic (DGT). To ensure the improvement possibilities that these tests and trials will bring in terms of road safety and safe and sustainable mobility in Spain and, at the same time, to contribute to boosting the automotive industry and investment in research in our country, this instruction is published and aimed at regulating the granting of special authorizations to conduct tests or research trials of automated vehicles on roads open to general traffic.

The requirements for obtaining authorization to undertake automated vehicle testing are the following: with reference to de Article of RD 2822/1998 of 23th December General

Regulations on Vehicles (GRV) manufactures of automated vehicles, their body-builders and official laboratories may apply for this authorization, more over manufacturers or installers of the technology that allows the vehicle to be fully automated, universities and consortia involved in the research projects will also apply or the authorization.

The final decision, either granting or refusing the special authorization requested, shall be issued by the Deputy Director-General for Mobility Management within one month of its registration on the Directorate-General for Traffic register.

The procedure for obtaining the certification of vehicles for carrying out the tests of autonomous driving on roads open to traffic has the objective to ensure the maximum level of safety for people involved performing these tests as well as for the other road users. The procedure consists of three parts: documentation (technical specifications, risk assessment, system functionality, testing scenarios...), inspection by and Authorized Technical Service and dynamic checks.

9. National activities to promote deployment of autonomous vehicles

9.1. Technical and organizational groups

9.1.1. UNITED KINGDOM

The UK Government has established and funded a number of connected and autonomous vehicle initiatives.

The Centre for Connected and Autonomous Vehicles (CCAV) was established in July 2015. The CCAV is a joint DfT/Department for Business, Enterprise and Industrial Strategy (BEIS) policy unit, with responsibility for:

- innovating policy development in this sector;
- delivering a programme of research, development, demonstration, and deployment activity, worth up to £250 million, through Innovate UK;
- providing co-ordination across DfT, BEIS and the rest of government; and
- being the single contact point for stakeholder engagement.

The CCAV currently focuses its work on three areas:

- Regulation – ensuring a welcoming regulatory framework to keep the UK at the forefront of real-world testing, and using automated vehicle technology
- Research and Development – collaborative R&D grants for developing cutting edge technologies, and

- Testing infrastructure – match funded grants to develop world leading testing ecosystem that's easy to access

Innovate UK is the UK's innovation agency. It is part of UK Research and Innovation, a non-departmental public body funded by a grant-in-aid from the UK government. Innovate UK funds business and research collaborations to accelerate innovation and drive business investment into research and development. Innovate UK runs grant funding competitions across multiple sectors.

The Catapult centres are a network of world-leading centres designed to transform the UK's capability for innovation in specific areas and help drive future economic growth. The Catapult network was established by and is funded through Innovate UK. There are ten Catapult centres covering a range of innovation areas. The Transport Systems Catapult is the UK's technology and innovation centre for Intelligent Mobility with a number of specialists and projects relating to Connected and Automated Vehicles.

9.1.2. GERMANY

The Federal Government is committed to creating an optimum regulatory framework and the necessary conditions for the introduction of automated and connected driving systems. In 2013, the Federal Ministry of Transport and Digital Infrastructure established the "Automated Driving" Round Table, an advisory body that enables a close exchange of ideas and experience among stakeholders from industry, academia, associations and public administration and pools the required know-how in such a way that a broad-based societal consensus can be achieved on all relevant aspects of automated and connected driving. The Round Table meets twice a year and has, among other things, determined which research areas are to be considered when developing automated driving.

On 20th June 2017, the Ethics Commission on Automated and Connected Driving presented its report, including 20 ethical rules. This independent Commission, chaired by Prof. Udo Di Fabio, a former judge at the German Federal Constitutional Court, was established by the minister of transport and digital infrastructure in September 2016. It received the mandate to develop ethical guidelines for new technologies like automated and connected driving. The Commission includes distinguished experts from academia, society, the automotive industry and the digital technology sector. The final report can be downloaded from the webpage of the Federal Ministry of Transport and digital Infrastructure.

9.1.3. SPAIN

The Spanish Association of Connected Autonomous Vehicles (AEVAC) was born in 2017 to promote an intelligent mobility model that guarantees equal opportunities for all people, using the technologies provided by the connected autonomous vehicle. Its mission is to promote the development and adoption of intelligent and autonomous mobility technology solutions that guarantee the full independence of all people.

AEVAC aims to promote the creation of an innovative ecosystem that links the public sector with companies and start-ups interested in this type of technology, as well as with third sector entities that work with mobility measures.

9.2. Standardization groups

There are several standardization groups that are related to autonomous vehicle and infrastructure interactions and concerned actors should keep track of the work of the following groups:

ISO TC204 WG14: Vehicle/roadway warning and control systems

Standardization of information, communication and control systems in the field of urban and rural surface transportation, including intermodal and multimodal aspects thereof, traveller information, traffic management, public transport, commercial transport, emergency services and commercial services in the intelligent transport systems (ITS) field.

ISO TC22 WG31: Data communication

Data communication for vehicle applications. This includes data buses and protocols (including dedicated sensor communication), V2X communication (including V2G), diagnostics, test protocols, interfaces and gateways (including those for nomadic devices), data formats, standardized data content.

CEN TC278 WG 16: Cooperative ITS

Cooperative ITS (C-ITS) has the potential to further increase the benefits of ITS services and applications. C-ITS is a subset of the overall ITS that communicates and shares information between ITS Stations to give advice or take actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone ITS.

CEN TC226 WG 12: Road interaction - ADAS / Autonomous vehicles

To prepare specifications for safety, traffic control and other road equipment in the following fields: a) Safety fences and barriers, including guard rails, safety fences, crash barriers, crash absorbers and bridge parapets; b) Horizontal signs including road studs and road markings; c) Vertical signs including signs, cones and marker posts; d) Traffic lights including signals, traffic control and danger lamps; e) Street lighting, performance requirements only; f) Other equipment including bollards, anti-glare screens and noise protection devices.

9.2.1. NATIONAL LEVEL AND MIRROR GROUPS

- United Kingdom

Currently vehicles are subject to a sophisticated, international system of type approval before they may be placed on the road. Standards are set by both the United Nations Economic Commission for Europe (UNECE) and the European Union (EU). Any new EU regulations in the short term, are likely to become UK law. In the longer term, the UK Government has proposed to maintain a "common rulebook" with the EU, which would include the EU system of type approval for all categories of motor vehicles.

In 2016, the British Standards Institute (BSI) and the Transport Systems Catapult, supported by the CCAV, began research to explore the priorities for standards to support the development and deployment of Connected and Autonomous Vehicles in the UK. The central findings of Connected and autonomous vehicles – A UK standards strategy, published in March 2017, highlight that standardization is required to help overcome barriers associated with CAV development, such as interoperability or public acceptance issues, while helping accelerate the deployment of the technologies, concepts and models for the industry.

In December 2018, the BSI published a cyber security standard for developing self-driving car technology. This work was funded by the Department for Transport and was developed on collaboration with academics and experts from leading businesses in the car industry including Jaguar Land Rover, Ford and Bentley, as well as the National Cyber Security Centre.

- Spain

The National Accreditation Entity - ENAC - is the entity designated by the Government to operate in Spain as the only National Accreditation Body, in application of Regulation (CE) nº. 765/2008 that regulates the operation of accreditation in Europe, which is based on five fundamental principles: Non-profit, Independence, Non-competition, International Evaluation and Mutual Recognition. Among its accredited services is the inspection of autonomous vehicles prior to their authorization to circulate on roads open to traffic.

9.3. National strategies

9.3.1. FRANCE

The ministry of transport release an official report on autonomous vehicle, the team behind this report led by Anne-Marie Idrac focused on the many challenges and economic stakes around autonomous mobility and gives strategic directions from the point of view of the state. Those directions cover many aspects that range from the expected actions of road operators to marketing scope of specific SAE levels. It also define the basics of the state's outlook about autonomous mobility and what information they need in order to launch specific call for project.

9.3.2. GERMANY

In September 2015, on the basis of recommendations made by the "Automated Driving" Round Table, the Federal Government published the "Strategy for Automated and Connected Driving - Remain a lead provider, become a lead market, introduce regular operations", thereby adopting guidelines on how to exploit the opportunities for growth and prosperity inherent in automated and connected driving. These technologies harbour the potential to increase road safety and traffic efficiency, reduce traffic-related emissions and strengthen Germany as a competitive business site for economic activity and a more attractive location for innovative businesses.

The implementation of the strategy, which was supported by members of the Automated Driving Round Table, triggered measures in five fields of action:

- Infrastructure: the deployment of a high-performance digital network infrastructure is designed to make it possible to connect vehicles with one another and with the road infrastructure in real time. Road infrastructure is to be designed according to digital mobility requirements.
- Legislation: the deployment of automated and connected vehicles needs legal certainty. This applies to both users and industry. Here, the following principle must apply: the proper use of automated and connected vehicles is not a breach of the driver's duty to exercise due diligence.
- Innovation: the potential for growth and prosperity inherent in automated and connected driving is to be leveraged where there is development, research and production. The trialling of appropriate technologies on test beds in real-life situations plus research into new issues in connection with their deployment is a key prerequisite for ensuring that these systems work properly and are safe and for assuming a position at the forefront of market introduction and penetration.
- Connectivity: interaction between vehicles and infrastructure presupposes the collection, processing and intelligent linkage of data. Automated and connected driving requires accurate information, i.e. on the traffic situation, spatial conditions, the state of the infrastructure and the weather situation.
- Cyber security and data protection: the digitalization of mobility and the associated increase in the amount of data are creating new requirements to be met by cyber security for vehicles and infrastructure and the protection of data. Automated and connected driving systems thus require clear and internationally applicable cyber security standards and data protection requirements.

Societal dialogue plays a key role in implementing the Strategy for Automated and Connected Driving. Automated and connected driving will be gradually developed and introduced. Road traffic will be characterized by mixed-traffic for many years, which means that we will see both vehicles with and without automated and connected driving functions. For this reason, strategies must be developed for the introduction of these new

technologies in order to make them as beneficial as possible for society as a whole. Other key action areas include considering opportunities, benefits and risks associated with the new technologies and promoting an exchange of experience between industry, academia and the various groups in society. In addition, an independent Ethics Commission, with members from the scientific community, the automotive industry and the digital technology sector as well as associations, is focusing on ethical questions related to the introduction of higher levels of automation in complex traffic situations.

The final report was published in November 2017 and can be found on the webpage of the Federal Ministry of Transport and digital Infrastructure.

9.3.3. FINLAND

The Ministry of Transport and Communications Finland has developed a plan for promoting intelligent automation in transport services. It was published in 2015 and calls for creating a strong shared determination for Finland to become one of the world's foremost actors in the field of intelligent automation of transport and to create and maintain an enabling regulatory framework that will make this development possible, publication “Robots on land, in water and in the air. Promoting intelligent automation in transport services - Robotit maalla, merellä ja ilmassa. Liikenteen älykkään automaation edistämissuunnitelma” (Pilli-Sihvola et al., 2015).

To promote automated driving, the Ministry and other road and transport authorities have developed a roadmap for automated driving. The roadmap “A roadmap for developing automation and robotics in transport sector 2017-2019 - Liikenteen automaation ja robotiikan kehittämistoimenpiteiden tiekartta 2017-2019 (Arola et al., 2017) was published in 2017 and describes the most important activities to be undertaken in order to facilitate automated driving trials and to prepare for increasing vehicle automation.

9.3.4. SPAIN

The Innovation Plan for Transport and Infrastructures 2018-2020, framed within the Europe 2020 Strategy and the 2017-2020 State Plan for Scientific, Technical and Innovation Research, aims at coordinating and integrating the innovation activities of the companies and institutions of the Fomento Group. The plan also seeks to promote open innovation, reinforcing collaboration with universities and the private sector.

The actions and initiatives presented in this plan are based on four strategic areas or dimensions: Digitalisation, Internet of the future, Intermodality and Energy transformation.

The objectives of the Plan include defining standards and regulations to ensure communications between vehicle and infrastructure, which are key to the expansion of the autonomous vehicle and ensuring the interoperability of the system for which the initiatives "Technical standardisation for the development of the Autonomous Vehicle Legal Framework" and "Publication of the White Paper on the Ethics of the Autonomous Vehicle" will be carried out.

9.4. Actions initiatives

9.4.1. FRANCE

EVRA[3] - Directly in line of the French state's strategic directions a call for project have been launch in 2018, they plan on a full-scale experimentation that bring together several actors of the fields (manufacturer, academics, transporters …) and cover as many aspect as possible of autonomous mobility including private cars, public transportation and freight. The goal of this call for project for the state is to initiate a common good on a national level, from the technological aspect to the social impact.

9.4.2. SPAIN

In September 2018, Red.es published the call for grants for pilot projects of 5G technology. 5G is expected to provide Ultra-Reliable and Low Latency Communications (URLLC) in the region of 1 millisecond (ms), as opposed to the 20-30 ms of 4G networks. This condition could make them suitable for applications that have specific requirements in this area, such as the connected vehicle or the autonomous vehicle. The projects submitted to this call must have three objectives : to support the deployments of the first 5G networks, to experiment with the network management techniques allowed by this technology and to develop use cases with the involvement of all actors, including users.

[3] Road Autonomous Vehicle Evaluation

10. Summary and Conclusion

10.1. Summary of requirements

10.1.1. ROAD NETWORK OPERATORS

- Consistency and continuity:

Car manufacturers need consistency within network but also between networks, without too much local particularities that would require special treatment, for things like road markings, signs, road surface quality, traffic management strategies and maintenance processes.

Network manufacturers may also have to set up some processes to ensure landmarks will be consistently visible and available for automated vehicles to position themselves on the road.

Adhering to European standards or guidelines will help to ensure cross-border interoperability and have the added benefit of avoiding the replication of work done elsewhere.

- Digital infrastructure:

Network operators will have to invest in the digital infrastructure, take a leading role in its development to ensure public expectations and objectives are met. They also will have to share their data (traffic, events, management strategies, circulation plans, etc.).

Together with relevant service providers, they will have an instrumental part to ensure the availability of good quality real-time information on road conditions, traffic, weather, incident and event. This will have to be done through a single access point.

Ensure sustainable service provision with long-lasting agreements and contracts with the relevant stakeholders will be necessary for the long term viability of the digital infrastructure and the safety of all road users.

- Maintenance and network management processes:

It is possible that upgrading procedures and quality controls to ensure that the expected level of service is indeed consistently reached on the network will be necessary.

Network operators will have to set up asset management and maintenance process to ensure good signs and markings visibility event in difficult weather as well as good quality of the road surface which meets the expectations. Furthermore, they will also have to ensure that redundant landmarks for location, suitable communication channels hardened against adverse weather, etc.

- Road classification:

If the choice to open only some road to automated driving system or to favour routing on certain roads while avoiding other, an extensive inventory and classification of the road

network will have to be carried. Subsequent upgrades will have to be broadcast to autonomous driving stakeholders.

10.1.2. STATES AND EUROPEAN LEVEL: LEGAL AND NORMATIVE FRAMEWORK

A legal framework to proactively protect consumers and network operator rights and interest before overreaching “end user agreement” will certainly be needed, since it was needed in other similar fields (telecommunication, software, etc.).

A legal framework to allow independent researchers to analyse and audit automated driving systems without have to risk facing legal action while allowing industry stakeholders to reasonably preserve their commercial interests would help strengthen the security and safety of the automated driving ecosystems.

A clarification of the repartition between stakeholders will be necessary to ensure industry members have incentives to design automated driving system with road safety as a key and overruling requirement. This should be done preferably at the largest possible level, i.e. at the European level.

Since type homologation is done at European level, it should be also done so for automated vehicle type-homologation. Given that procedures will probably be more complex and expansive to design, this would avoid replicating costly work both for manufacturer and public stakeholders.

Data privacy agencies (ombudsmen) already exist in European countries. Specific regulation may be necessary for automated driving systems.

10.2. Conclusion

This deliverable describes the state of the art of the automated driving, the expectations on it, the ODDs (Operational Design Domains) related to the automated driving use cases and the expected requirements toward physical and digital infrastructure. In addition, it discusses topics related to legal and regulation framework, and national policies and approaches to facilitate automated driving as well as aspects of cyber security and data privacy.

While the general public mostly expects improved safety, comfort and to gain back some free time it invested in its travels, road network operators expect safety and efficiency improvements from the roll-out of automated vehicles on their networks. To meet these expectations, car manufacturers and service providers will need to work together with road network operators in order to define the right balance between comfort, safety and efficiency. Furthermore, road network operators need to comply with strict economic constraints and also have to provide service to all road users: automated vehicles, manual vehicles, public transport vehicles, bikes and pedestrians alike. Hence, they will not be able to undertake comprehensive network transformations in a short time period to accommodate automated driving vehicles.

Automated driving systems are still in heavy development and even if systems ranked up to Level 4 will be available on the general market in the upcoming decade. Level 5 systems are still a long way from being ready for commercialization.

The present report is based on what is currently known about advanced automated driving systems, on educated guesses by experts in the field of road transportation and not on requirements and needs expressed by car manufacturers and services providers. Those needs and requirements are just starting to emerge as progresses are made toward fully automated vehicles. It is also likely that the enhancement of sensor and software solutions due to technology development accompanied with the economics of mass production will provide extensions of the ODDs of automated vehicles in the next decades. This would result in relaxed requirements towards physical and also digital infrastructure. However, the actual developments in this respect are difficult to predict.

As automated vehicles will be introduced gradually, road operators will have to accommodate partially automated, fully automated and human drivers for a long time. It is important to find affordable solutions that accommodate also automated vehicles. Leveraging the advantages of automated driving systems should be done as soon as possible to offset the costs induced by having the different types of vehicles simultaneously on the network.

As long as there is a mix of automated and non-automated vehicles, design parameters for roads are obviously based on the manual operation of vehicles. This means that altering the roads in the sense that elements are taken away (e.g. lane markings, signs) or will have other dimensions (e.g. narrower lanes) is out of the question. However, adding elements to the existing infrastructure to facilitate or enhance automated driving without negatively affecting manual driving, is a possibility (e.g. connectivity, landmarks).

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